Development of Terrorist Attack Scenarios Against The Air Transportation System

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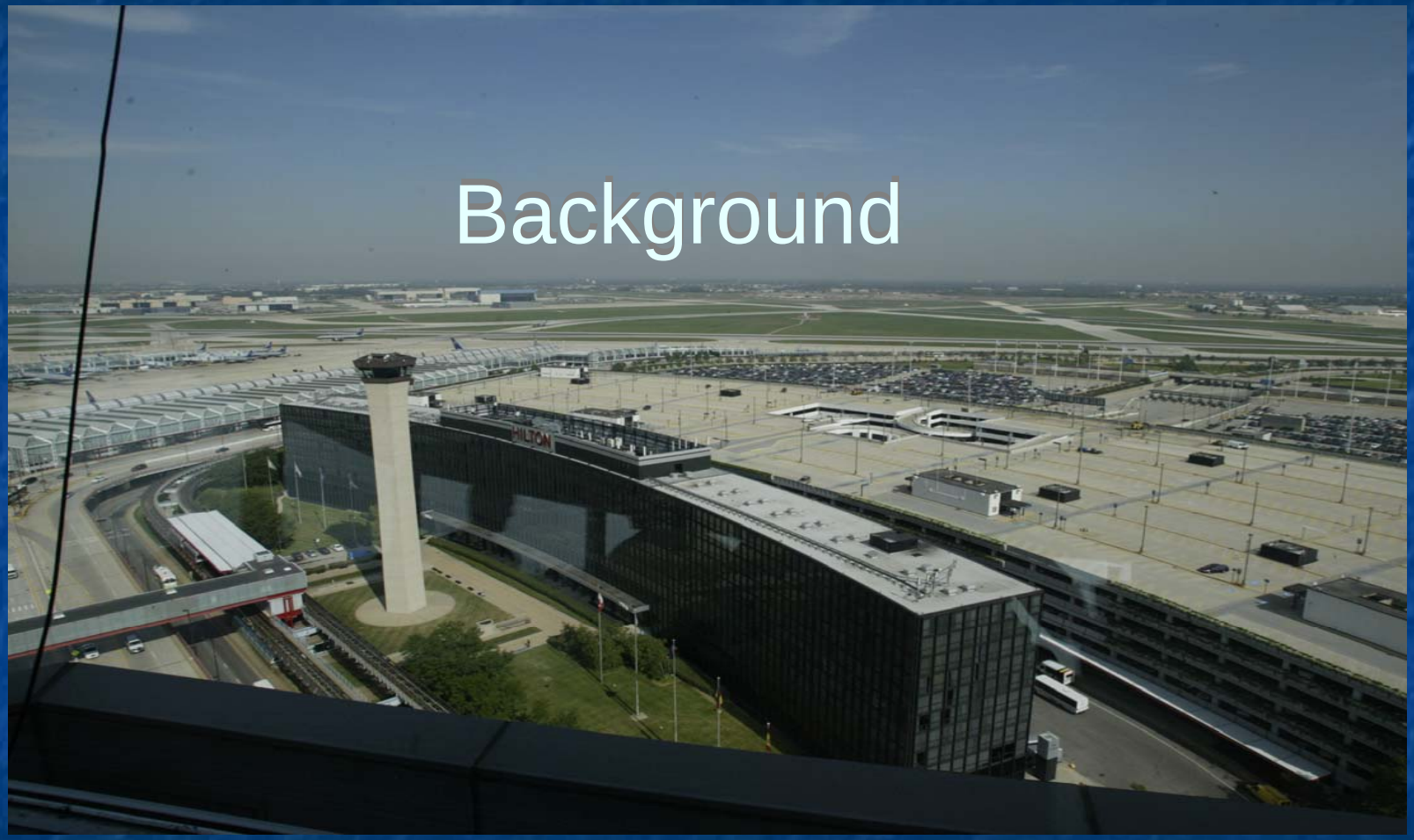
Problem: Estimating the risk of terrorism to a system depends upon the range of attack scenarios available to the adversary.

Approach: Use logic gate trees (LGTs) to represent subject matter expert (SME) knowledge in a model that provides the basis for the risk analysis. The LGTs are developed using the Logic Evolved Decision (LED) methodology.

Presentation Outline

- Background
- Structure of an attack scenario
- LED model for aviation transportation system
- Scenario groupings, CONOPS and technology insertions
- Expert elicitation
- Conclusions

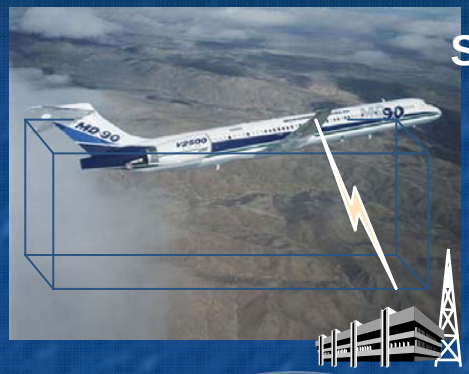
Background



Risk-based Prioritization of NASA Aviation Security Research

- NASA Goal:
  - **Use a *top-down analysis* approach to rank order security technology investments**
- Objective:
  - **Decision support tool to prioritize aviation security research**
  - **Based upon an air transportation system (ATS) risk assessment**
- Technical Challenges:
  - **Pioneering development effort**
  - **Security assessments for the entire ATS**
  - **Extensive integration of subject matter experts**

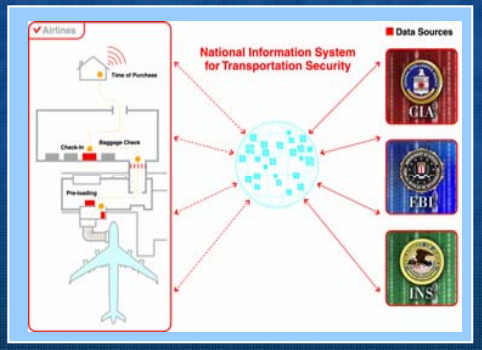
NASA Approach to Aviation Security



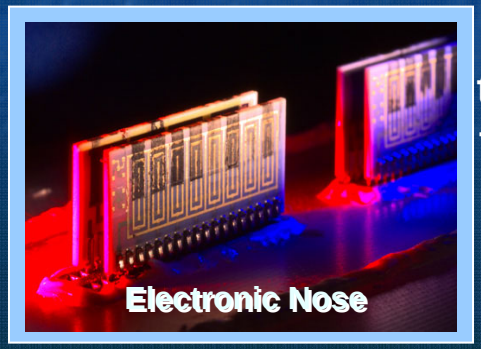
Secure and protect the aircraft

Harden the National Airspace System

Secure vehicle CNS systems

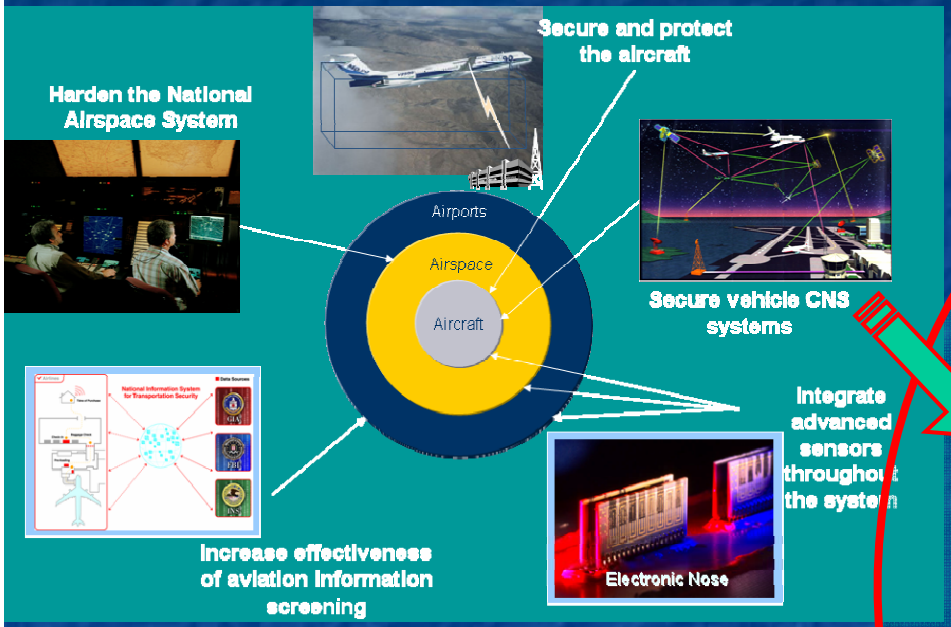


Integrate advanced sensors throughout the system



Increase effectiveness of aviation information screening

Assessing Air Transportation System Risk



Risk Assessment Approach to Aviation Security

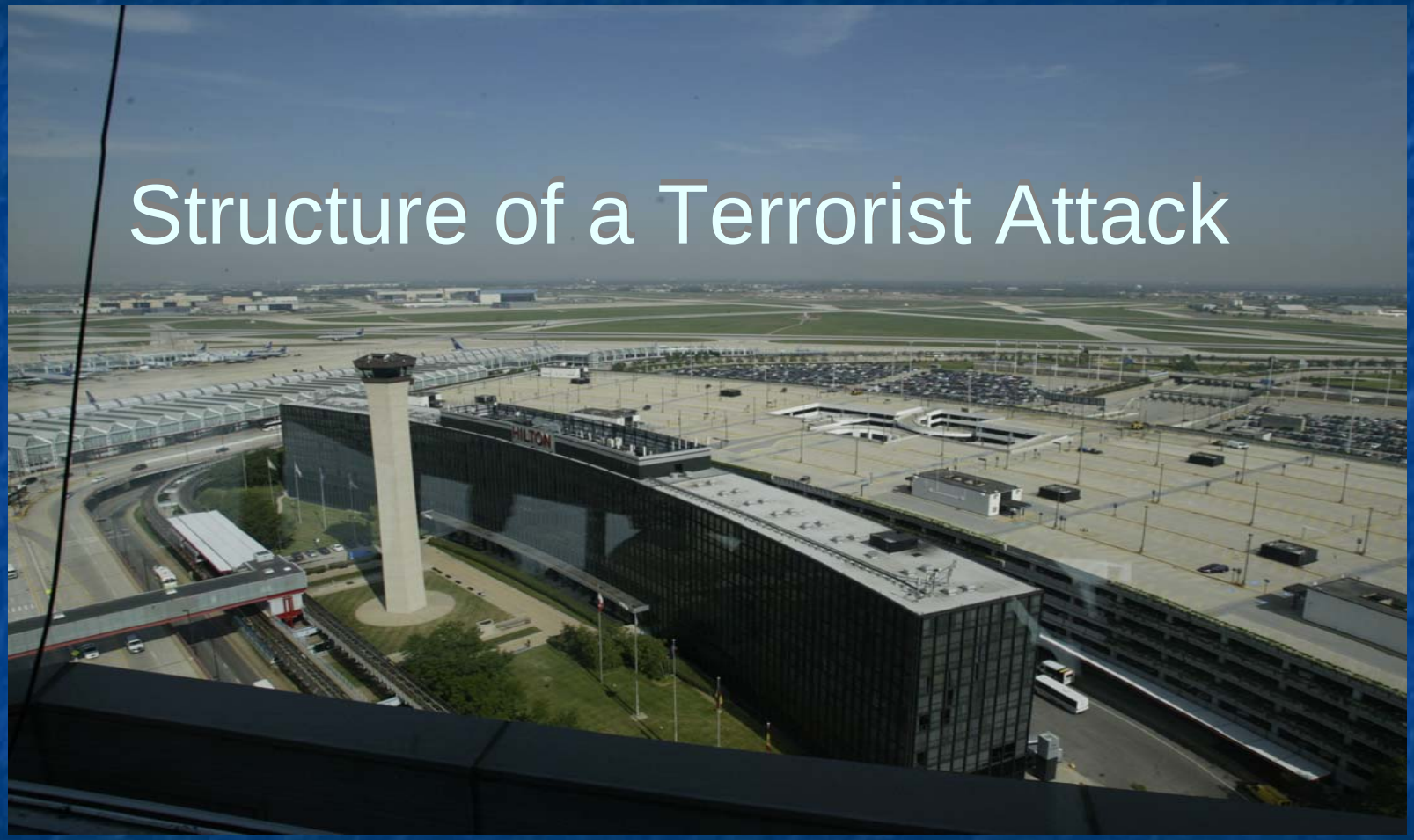
- ATS Divided into Three Sub-systems
- Aircraft Further Decomposed into Federal Aviation Regulation Parts

Aircraft

- Part 121 Passenger/Cargo
- Part 121 All Cargo
- Part 135
- Part 91

Airport

Airspace

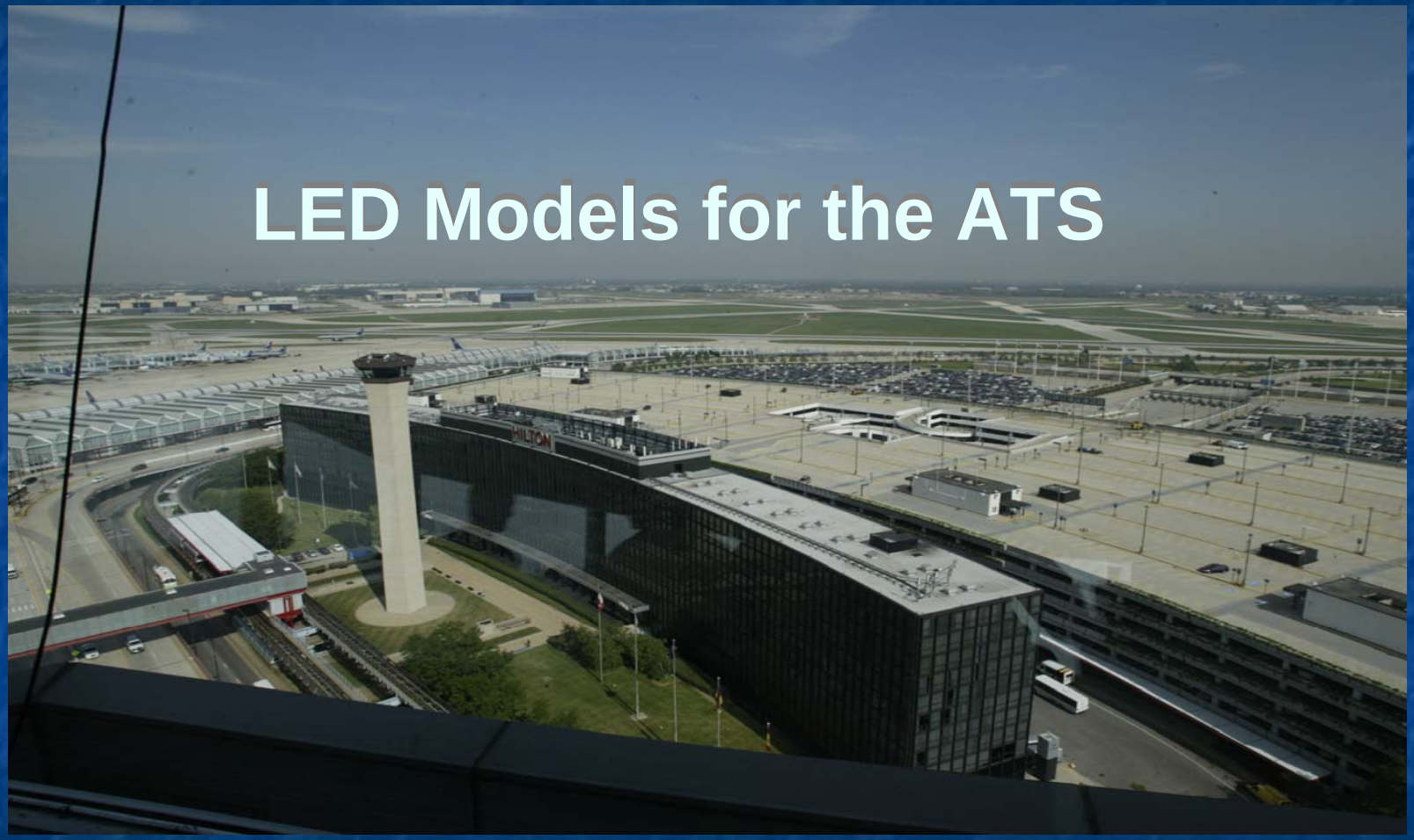

Structure of a Terrorist Attack

An Attack Scenario Is A Process

Target Selection → Planning → Logistics → Assault → Target Response

Attacker

For the ATS a very large number of scenarios are possible

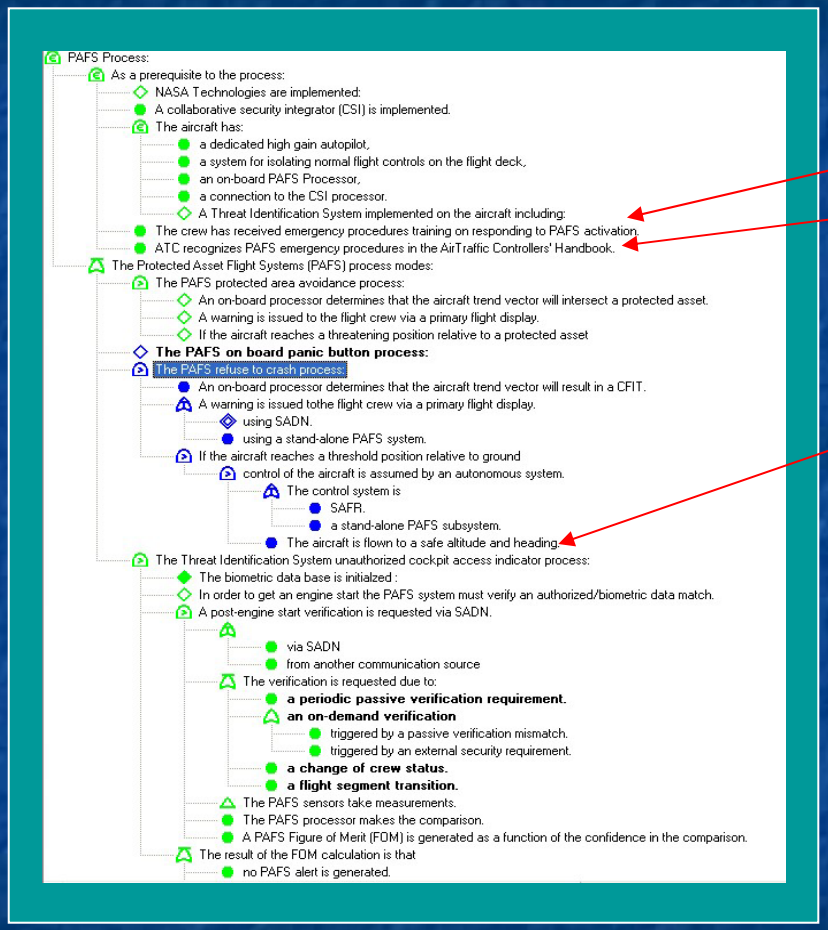


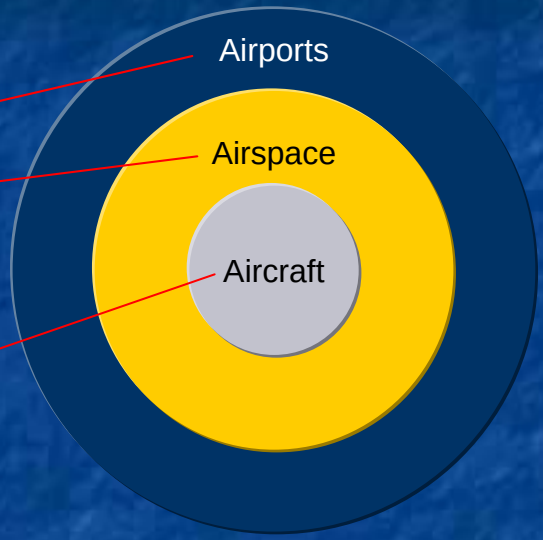
LED Models for the ATS

Possible Scenarios Are Generated Using LGTs with LED

1. **Develop a Possibility Tree**
   - Composed of elements of a process
   - Logical operators (i.e., *and* / *or*) connect elements
   - Deduction facilitates capturing a large set of possible scenarios
2. **Solve the Possibility Tree**
   - Generate scenarios from logically linked elements
   - Prune the tree to develop a spanning set of scenarios

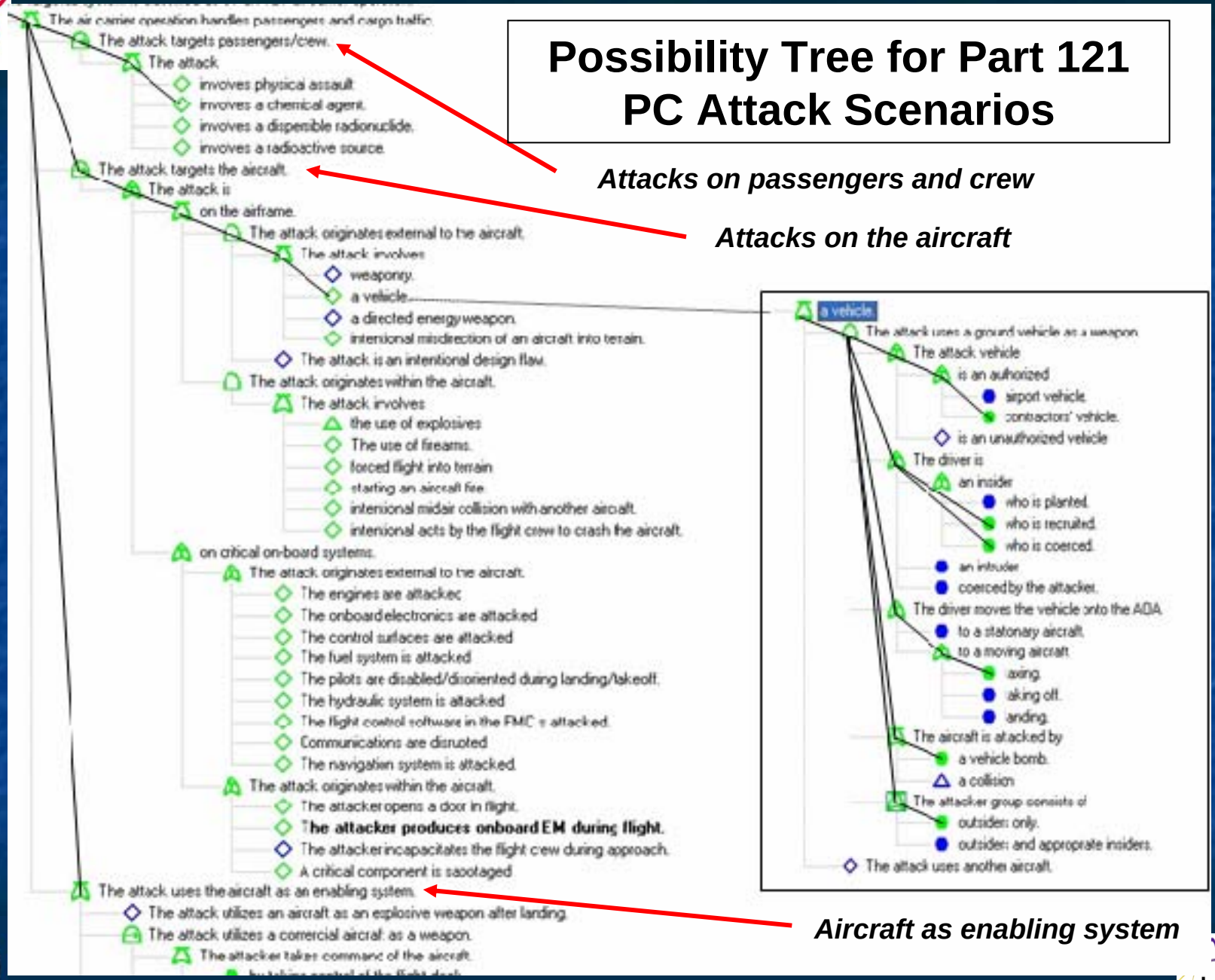
Super Tree for the ATS





LGTs allow for convenient modularization of the attack space

Possibility Tree for Part 121 PC Attack Scenarios



Attacks on passengers and crew

Attacks on the aircraft

Aircraft as enabling system

Sub-trees Consider Specific Types of Attacks

Target

- The attack targets the aircraft.
  - The attack is
    - on the airframe.
    - The attack originates external to the aircraft.
      - The attack involves
        - weaponry.
          - The weapon used
            - is a missile launcher.
            - is a man-portable missile.
              - The missile is
              - The attacker acquires the weapon system.
                - The attack system is purchased.
                  - The source is a foreign nation.
                  - The source is an arms dealer.
                - The attack system is stolen.
                  - The source is a foreign military.
                  - The source is an arms dealer.
                  - The source is the US military.
                - The attack system is supplied.
                  - The source is a foreign military.
                  - The source is a terrorist organization.
              - The attacker transports the missile system to the attack site.
              - The attacker acquires the target.
              - The attacker fires the missile.
              - The missile flies to the target.
              - The missile warhead
                - detonates.
                - fails to detonate.
              - The attacker group consists of
                - outsiders only.
                - outsiders and appropriate insiders.

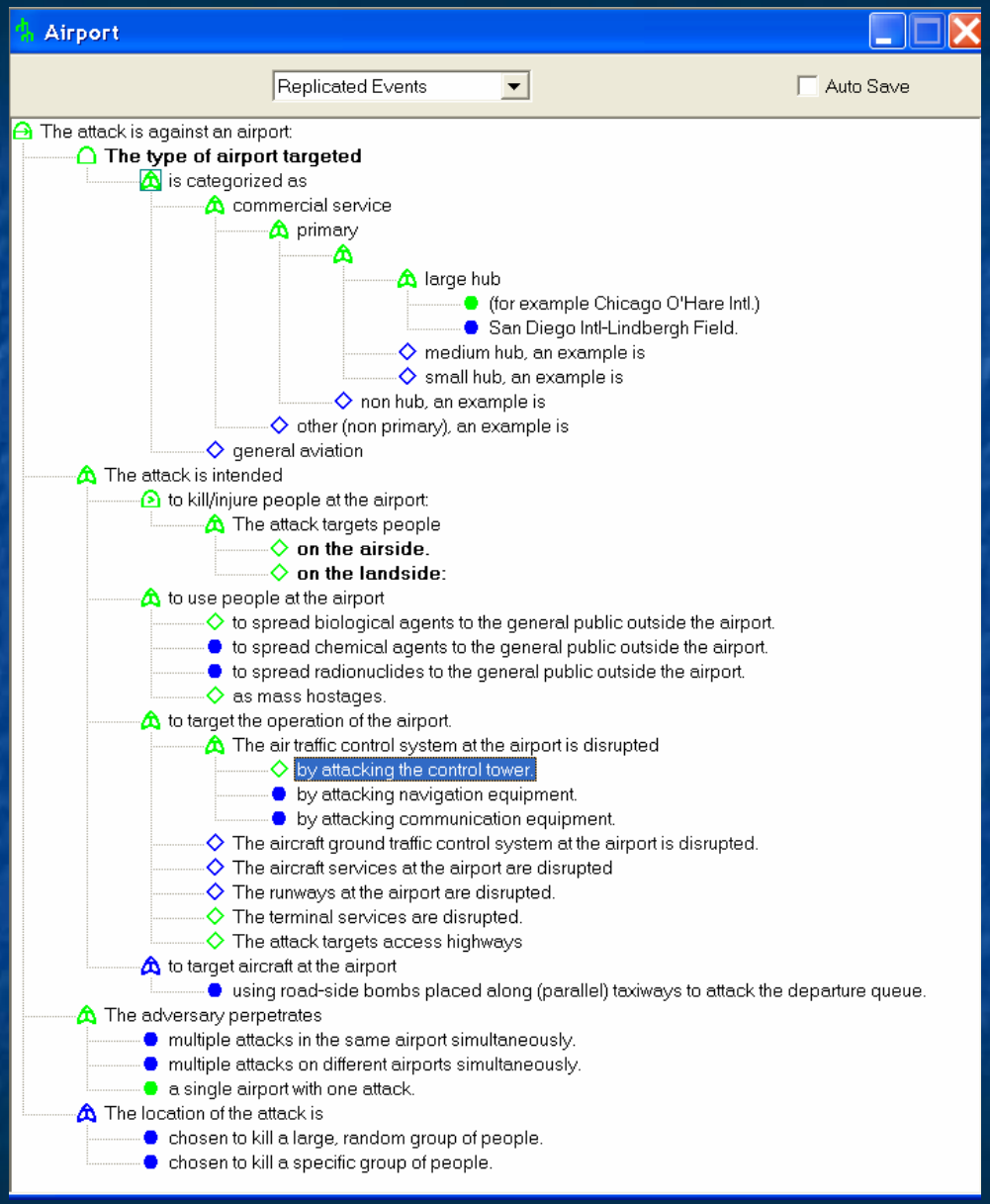
Weapon

Logistics

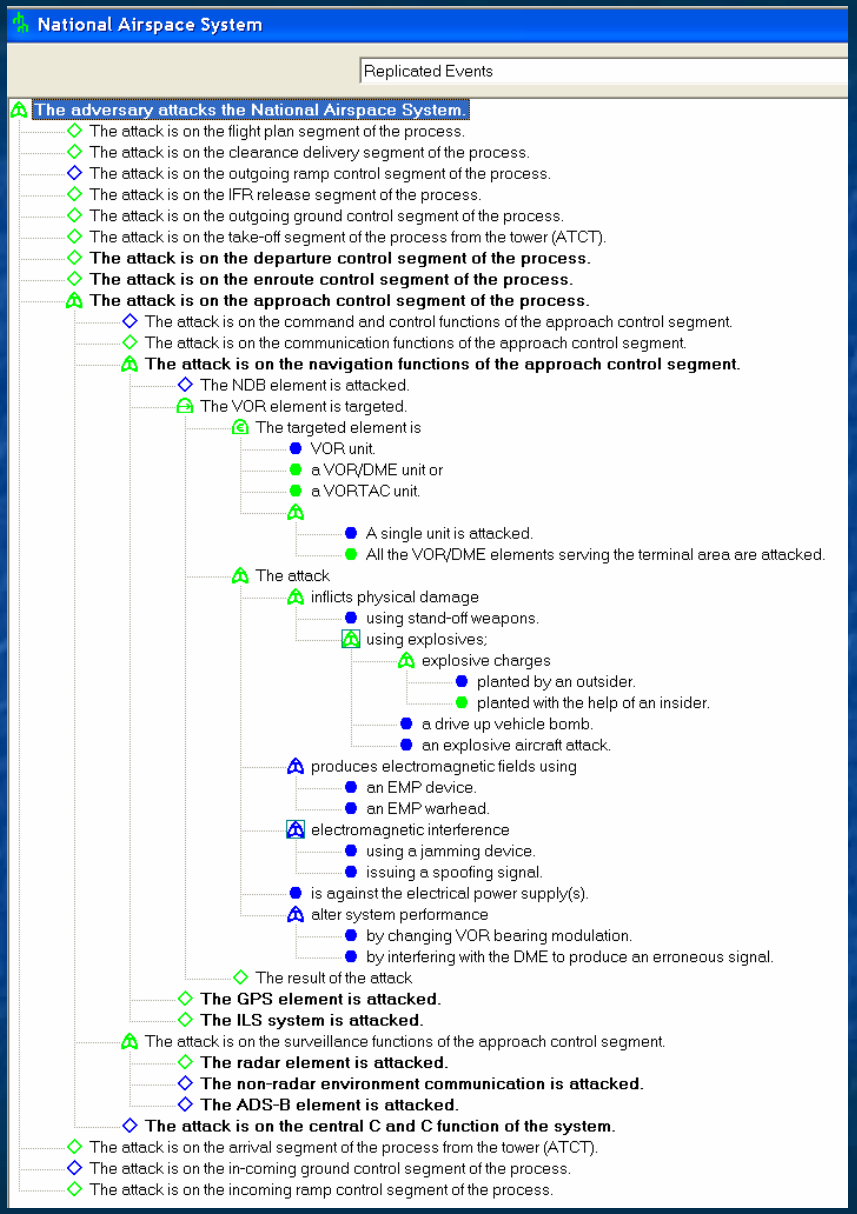
Assault

Target Response

Airport Tree



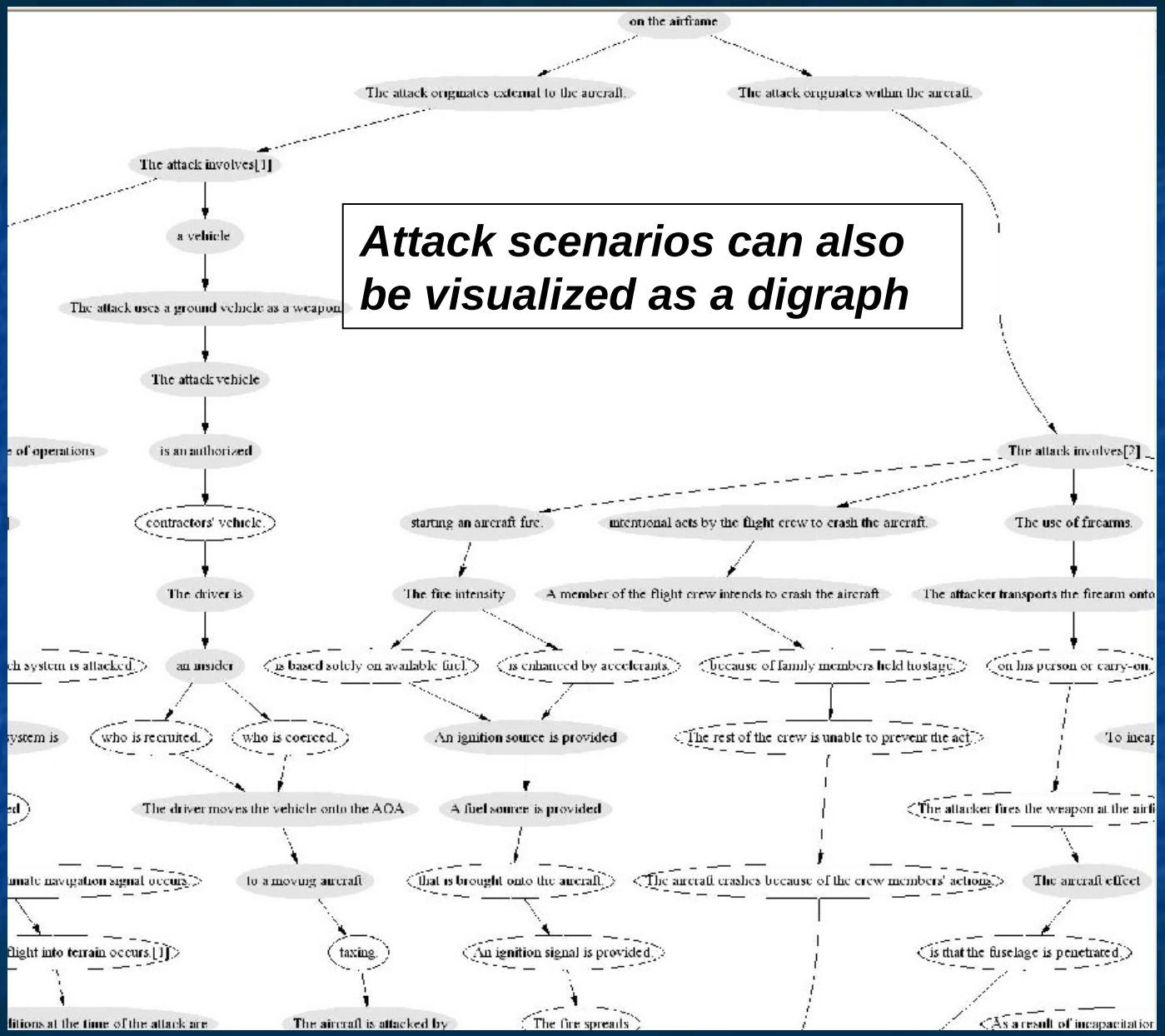
Airspace Tree



The Possibility-Tree Solution Gives a Comprehensive Set of Attack Scenarios

Attack on the US aviation system. Attack is against the commercial aviation system. The targeted system is classified as a Part 121 air-carrier operation. The air-carrier operation handles passenger and cargo traffic. The attack targets the aircraft. The attack is on the airframe. The attack originates external to the aircraft. The attack involves weaponry. The weapon used is a man-portable missile. The attacker acquires the weapon system. The attacker transports the missile system to the attack site. The attacker acquires the target. The attacker fires the missile. The missile flies to the target. The missile warhead detonates. The attacker group consists of outsiders only.

Attack scenarios appear in natural language form for use with SMEs


on the airframe
The attack originates external to the aircraft.
The attack originates within the aircraft.
The attack involves[1]
a vehicle
The attack uses a ground vehicle as a weapon
The attack vehicle
is an authorized
contractors' vehicle.
The driver is
an insider
who is recruited.
who is coerced.
The driver moves the vehicle onto the AOA
to a moving aircraft
taxing.
The aircraft is attacked by
The attack involves[?]
starting an aircraft fire.
The fire intensity
is based solely on available fuel.
is enhanced by accelerants.
An ignition source is provided
A fuel source is provided
that is brought onto the aircraft.
An ignition signal is provided.
The fire spreads
intentional acts by the flight crew to crash the aircraft.
A member of the flight crew intends to crash the aircraft
because of family members held hostage.
The rest of the crew is unable to prevent the act.
The aircraft crashes because of the crew members' actions.
The use of firearms.
The attacker transports the firearm onto
on his person or carry-on.
The attacker fires the weapon at the airfi
The aircraft effect
is that the fuselage is penetrated.
Attack scenarios can also be visualized as a digraph

Scenario Groupings, CONOPS and Technology Insertions

Summary Attack Scenarios in Spanning Set for Part 121 PC Aircraft

Type of Attack	Number of Scenarios	Example
Attack on crew or passengers	4	Dispersion of chemical agent in passenger compartment
Attack on airframe	20	Missile attack with man-portable system
Attack on critical on-board systems	20	Jamming or spoofing of navigational aids
Use of aircraft as an enabling system for weapons-of-mass-destruction attack	4	Variations of 9/11 World Trade Center attack

Similar spanning sets were developed for airports and the air space in consultation with SMEs

A Scenario / Technology Crosswalk

Scenario

Technology

	PC-1	PC-2	PC-3	PC-4	AF-1	AF-2	AF-3	AF-4	AF-5	AF-6	AF-7	AF-8	AF-9	AF-10	AF-11	AF-12	AF-13	AF-14	AF-15	AF-16	AF-17	AF-18	AF-19	AF-20	OBS-1
Fire/Explosive Resistive Mat.					X*	X*	X*	X*		X*						X	X				X	X			
Protected Asset Flight System	X																	X	X	X			X	X*	
Damage Adaptive Control Sys					X	X	X	X	X		X	X*				X	X				X*	X*			X
Vehicle Recovery	X*															X*	X*	X	X	X			X	X*	
Electromagnetic Emissions EME												X*	X*	X	X										
Secure Aircraft CNS (SASIF)	X	X*										X*	X	X	X		X*	X	X	X			X	X	
Fuel Tank Inerting/Fire Prot.					X*	X	X	X*	X*	X						X	X	X*	X*	X*	X	X	X*	X*	
Chemical Agent Sensors		X	X*	X*												X*					X*				
Biological Agent Sensors								X																	

Technology

	OBS-2	OBS-3	OBS-4	OBS-5	OBS-6	OBS-7	OBS-8	OBS-9	OBS-10	OBS-11	OBS-12	OBS-13	OBS-14	OBS-15	OBS-16	OBS-17	OBS-18	OBS-19	OBS-20	OBS-21	AES-1	AES-2	AES-3	AES-4
Fire/Explosive Res. Mat.							X	X*																
Protected Asset Flight System									X*			X*				X*			X*		X*	X	X	
Damage Adaptive Control Sys	X	X			X*	X*	X*	X*		X*	X*							X*		X				
Vehicle Recovery									X								X*		X	X	X	X	X*	
Electromagnetic Emissions EME			X	X					X*				X	X	X			X		X*				
Secure Aircraft CNS (SASIF)			X*	X*					X*			X*	X	X	X	X*				X*		X		
Fuel Tank Inerting/Fire Prot.	X*	X					X	X											X*			X*		
Chemical Agent Sensors																							X	
Biological Agent Sensors																							X	X

Concepts of Operation Define Technology Insertion Points

- The DACS process:
  - As a prerequisite to the process
  - An event occurs on the aircraft
  - The effect on the aircraft is sensed
  - The DACS processor analyzes the event and its effect.
    - The DACS performs an automated Structural Damage Check.
    - The DACS determines trajectory and landing site guidance.
  - The DACS processor produces an aircraft state analysis
  - A DACS alert is generated.
    - Simultaneously,
      - the information is broadcast via SADN to the cabin area, informing cabin crew and Federal Air Marshalls (FAMs);
      - SADN recieves the alert and the preliminary damage assessment.
  - The DACS processor generates a controlled recovery strategy.
    - The remaining flight operating envelope is determined through onboard modeling and simulation.
    - Adaptive engine control is invoked.
    - Adaptive control recovery and reconfiguration is invoked.
    - The DACS is implemented by
      - If
      - **placing limits on aircrew flight control inputs to stay within the remaining operating envelope.**
      - If

CONOPS for Damage Adaptive Controls on Aircraft

The Role of Expert Elicitation

Many Different Types of SMEs Participated in the Analysis

- National Institute of Aerospace (NIA)
  - Aviation System Expert Consultants
- Aviation Operations
  - Pilots
  - Airport Managers
  - Air Traffic Controllers
- Air Force Research Laboratory (AFRL)
  - Electromagnetic Effects Expertise
- NASA Aviation Security Research Projects
  - Research Project Input to Analysis
- Volpe Center Department of Transportation (Volpe)
  - Cost/Benefit Studies
- Experts on terrorism from various agencies

SME Roles

- Definition of system for analysis
- Development of attack scenario possibility trees
- Selection of spanning sets
- Revision of trees and sets based upon initial risk assessment
- Development of CONOPS and identification of technology insertion points

Conclusions

- To be meaningful, terrorist risk analyses must have a well-defined set of attack scenarios
  - Logic gate trees provide a structured approach to scenario development
  - The possibility tree contains a very large set of scenarios
  - Spanning sets can be developed for different purposes
- An LGT model can be extended to incorporate CONOPS and to help define technology requirements
- Terrorist risk analysis is highly dependent on SME knowledge
  - Possibility trees are an efficient way to integrate large amounts of expert knowledge
  - A tree can be easily updated to reflect new information or modified as a result of SME interactions